7-23 August, 2016 - Visiting Scholar Program FEB, UNIMAS: Activity Plan

22 August, 2016: Lab Session on '**Methodological Issues**' 2.00pm – 5.00pm

ARDL Cointegration Tests for Beginner

Tuck Cheong TANG
Department of Economics, Faculty of Economics & Administration
University of Malaya
Email: tangtuckcheong@um.edu.my

DURATION: 3 HOURS

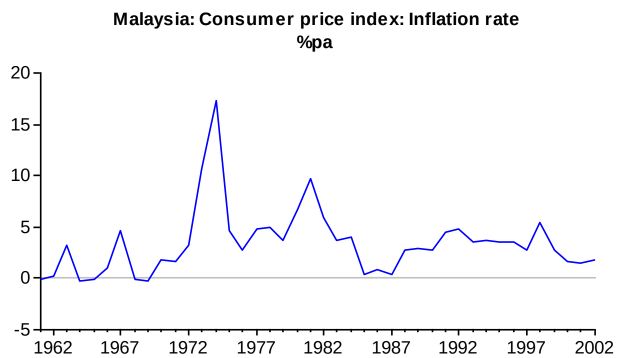
On completing this workshop you should be able to:

- understand the concepts of cointegration and its application as well.
- perform cointegration tests by using EViews software; and
- interpret the outputs and estimates.

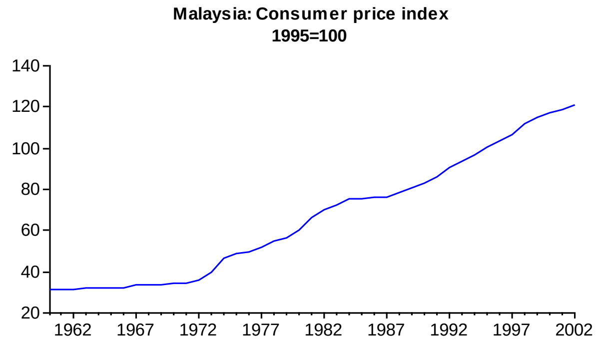
1. UNIT ROOT TEST

An estimate of OLS (ordinary least squared) regression model can *spurious* from regressing nonstationary series with no long-run relationship (or no cointegration) (Engle and Granger, 1987).

Stationary – a series fluctuates around a mean value with a tendency to converge to the mean. For example:-



Non-statioanry – a series wanders widely without any tendency to converge; it is relatively smooth. For example:-



Conventional tests for examining series stationarity:-

Type of tests	Null hypothesis
1. Augmented Dickey-Fuller (ADF)	a unit root
2. Phillips-Perron (PP)	a unit root
3. Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)	trend stationary or level stationary

Other types of tests are Dickey-Fuller Test with GLS Detrending (DFGLS), Elliot, Rothenberg, and Stock Point Optimal (ERS) Test, and Ng and Perron (NP) Tests

I(0) -> stationary in levels
I(1) -> non stationary in levels but it becomes stationary after differencing once.

2. COINTEGRATION

From econometric point of view, it is a solution to the problems that arise as a result of the presence of non-stationary data (OLS estimates), that is to avoid the problems associated with "spurious regression".

In practice, it is more appropriate to test a theory. Economic theory often suggests certain variables are cointegrated with know (or unknown) cointegrating vector. In order words, we use to test for the presence of an equilibrium relationship between the variables suggested by economic theory.

Because: - Evan though an economic time series may wander over time there may exist a linear combination of the variables that converges to an equilibrium, that is, the variables are cointegrated.

How: - Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated.

ARDL APPROACH FOR COINTEGRATION – SINGLE EQUATION APPROACH

The main advantage of this testing and estimation strategy (ARDL procedure) lies in the fact that it can be applied irrespective of the **regressors** are I(0) or I(1), and this avoids the pre-testing problems associated with standard cointegration analysis which requires the classification of the variables into I(1) and I(0) (Pesaran and Pesaran, 1997, p.302-303). Also see, Jenkinson (1986) for ARDL model for cointegration analysis.

ARDL (autoregressive-distributed lag) approach for cointegration by Pesaran, Shin and Smith (2001) can be performed via the error correction version of the ARDL model as:

$$\Delta y_t = c + \gamma_0 y_{t-1} + \gamma_1 x_{t-1} + \sum_{i=1}^{p-1} b_{1i}\Delta y_{t-i} + \sum_{i=1}^{p-1} b_{2i}\Delta x_{t-i} + u_t \quad \text{------------------------ (1)}$$

In testing for a long run relationship between *y* and *x*, we test H_0: $\gamma_0 = \gamma_1 = 0$ (non-existence of the long run relationship) against H_A: $\gamma_0 \neq 0, \gamma_1 \neq 0$ (a long run relationship) by running an usual F-test.

If the computed F-statistic falls outside the band (the values for I(0) and I(1) in the Table F), a conclusive decision can be made.

1) if the computed F-statistic exceeds the upper bound of the critical value band (denote I(1) in the Table F), the null hypothesis can be rejected and then support cointegration, and
2) if the computed F-statistic falls well below the lower bound of the critical value band (denote I(0) in the Table F), and hence the null hypothesis cannot be rejected – no cointegration.

If the computed statistic falls within the critical value band, the result of the inference is inconclusive and depends on whether the underlying variables are I(0) or I(1). It is at this stage in the analysis that the researcher may have to carry out unit rot tests on the variables.

The long run coefficient (or elasticity) of *x*, that is, β = -(γ_1 / γ_0) (see equation 1) (Pesaran, et al., 2001,p. 294).

Table F: Testing the existence of a long-run relationship: critical value bounds of the F statistic

Case I: no intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0.000	3.016	3.016	4.136	4.136	5.347	5.347	7.381	7.381
1.000	2.458	3.342	3.145	4.153	3.893	4.927	5.020	6.006
2.000	2.180	3.211	2.695	3.837	3.258	4.458	3.939	5.341
3.000	2.022	3.112	2.459	3.625	2.901	4.161	3.372	4.797
4.000	1.919	3.016	2.282	3.474	2.618	3.924	3.061	4.486
5.000	1.825	2.943	2.157	3.340	2.481	3.722	2.903	4.261
6.000	1.760	2.862	2.082	3.247	2.367	3.626	2.744	4.124
7.000	1.718	2.827	2.003	3.199	2.288	3.536	2.595	3.909
8.000	1.678	2.789	1.938	3.133	2.198	3.445	2.481	3.826
9.000	1.640	2.774	1.873	3.072	2.122	3.351	2.396	3.725
10.000	1.606	2.738	1.849	3.026	2.076	3.291	2.319	3.610

Case II: intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0.000	6.597	6.597	8.199	8.199	9.679	9.679	11.935	11.935
1.000	4.042	4.788	4.934	5.764	5.776	6.732	7.057	7.815
2.000	3.182	4.126	3.793	4.855	4.404	5.524	5.288	6.309
3.000	2.711	3.800	3.219	4.378	3.727	4.898	4.385	5.615
4.000	2.425	3.574	2.850	4.049	3.292	4.518	3.817	5.122
5.000	2.262	3.367	2.649	3.805	3.056	4.267	3.516	4.781
6.000	2.141	3.250	2.476	3.646	2.823	4.069	3.267	4.540
7.000	2.035	3.153	2.365	3.553	2.665	3.871	3.027	4.296
8.000	1.956	3.085	2.272	3.447	2.533	3.753	2.848	4.126
9.000	1.899	3.047	2.163	3.349	2.437	3.657	2.716	3.989
10.000	1.840	2.964	2.099	3.270	2.331	3.569	2.607	3.888

Case III: intercept and trend								
	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0.000	9.830	9.830	11.722	11.722	13.503	13.503	16.133	16.133
1.000	5.649	6.335	6.606	7.423	7.643	8.451	9.063	9.786
2.000	4.205	5.109	4.903	5.872	5.672	6.554	6.520	7.584
3.000	3.484	4.458	4.066	5.119	4.606	5.747	5.315	6.414
4.000	3.063	4.084	3.539	4.667	4.004	5.172	4.617	5.786
5.000	2.782	3.827	3.189	4.329	3.573	4.782	4.011	5.331
6.000	2.578	3.646	2.945	4.088	3.277	4.492	3.668	4.978
7.000	2.410	3.492	2.752	3.883	3.044	4.248	3.418	4.694
8.000	2.290	3.383	2.604	3.746	2.882	4.081	3.220	4.411
9.000	2.192	3.285	2.467	3.614	2.723	3.898	3.028	4.305
10.000	2.115	3.193	2.385	3.524	2.607	3.812	2.885	4.135

Source: Pesaran and Pesaran (1997) p.478 Appendices.

Notes: k is the number of the forcing variables (regressors)

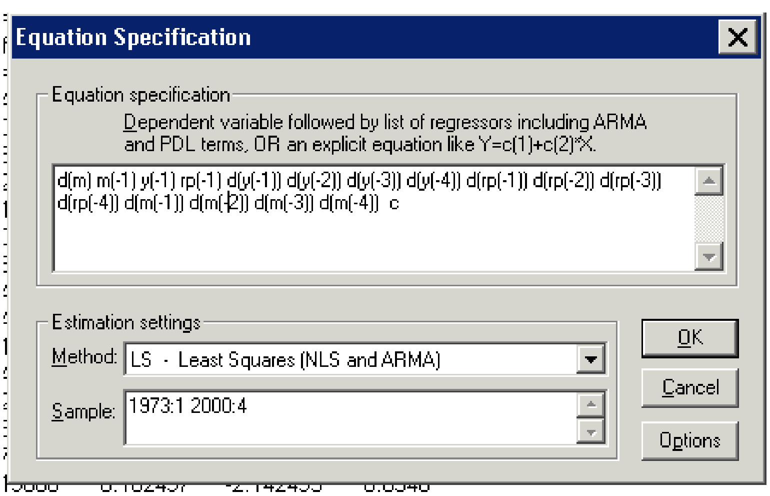
The critical value bounds reported in Table F above are computed using stochastic simulation for T = 500 and 20,000 replications in the case of Wald and F statistics for testing the joint null hypothesis that the coefficients of the level variables are zero (i.e. there exists no long-run relationship between them).

Further reading: Pesaran et al. (2001)

Eviews – by hands

- Investigate the presence of a long run relationship among *m*, *y* and *rp* with ARDL(lag length of 4, quarterly data) (assume an intercept and no trend).

Step 1:- OLS estimation for ARDL



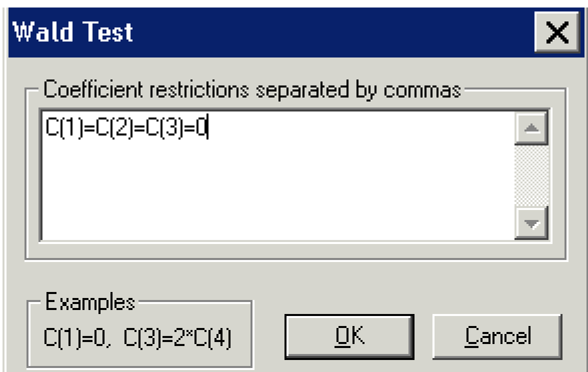
D(M) M(-1) Y(-1) RP(-1) D(Y(-1)) D(Y(-2)) D(Y(-3)) D(Y(-4)) D(RP(-1)) D(RP(-2)) D(RP(-3)) D(RP(-4)) D(M(-1)) D(M(-2)) D(M(-3)) D(M(-4)) C

Step 2:- Wald test (F-statistic) for restrictions. C(1)=C(2)=C(3)=0

```
Estimation Command:
=====================
LS D(M) M(-1) Y(-1) RP(-1) D(Y(-1)) D(Y(-2)) D(Y(-3)) D(Y(-4)) D(RP(-1)) D(RP(-2)) D(RP(-3)) D(RP(-4)) D(M(-1)) D(M(-2)) D
C

Estimation Equation:
=====================
D(M) = C(1)*M(-1) + C(2)*Y(-1) + C(3)*RP(-1) + C(4)*D(Y(-1)) + C(5)*D(Y(-2)) + C(6)*D(Y(-3)) + C(7)*D(Y(-4)) + C(8)*D(RP
(-2)) + C(10)*D(RP(-3)) + C(11)*D(RP(-4)) + C(12)*D(M(-1)) + C(13)*D(M(-2)) + C(14)*D(M(-3)) + C(15)*D(M(-4)) + C(16)

Substituted Coefficients:
=====================
D(M) = -0.04450853389*M(-1) + 0.004157266267*Y(-1) - 0.05627602468*RP(-1) + 0.2230020144*D(Y(-1)) + 0.411665047
0.008075956819*D(Y(-3)) + 0.667672946*D(Y(-4)) - 0.0411923347*D(RP(-1)) + 0.04957894891*D(RP(-2)) + 0.0144477080
0.04673148731*D(RP(-4)) + 0.02230693719*D(M(-1)) + 0.2622040107*D(M(-2)) + 0.07025321954*D(M(-3)) - 0.219599926
0.4567636779
```



Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.537631	(3, 91)	0.0178
Chi-square	10.61289	3	0.0140

The critical values at 0.10 level are 3.182 (lower bound) and 4.126 (upper bound) (k = 2, Case II: intercept and no trend case).
:- inconclusive (within the critical value band)

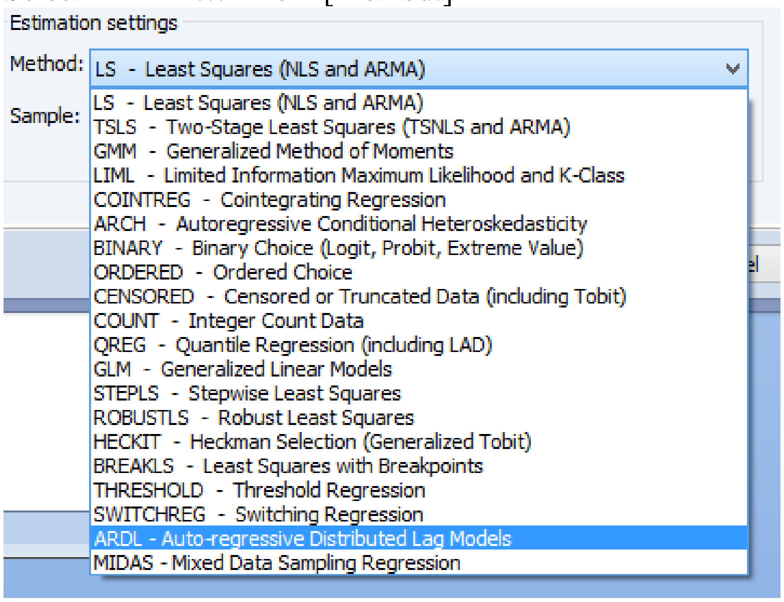
The 0.05 level critical values are 3.793 (lower bound) and 4.855 (upper bound)
:- no cointegration (below the lower bound)

- *Sensitivity check* – ARDL(8) and ARDL(12).

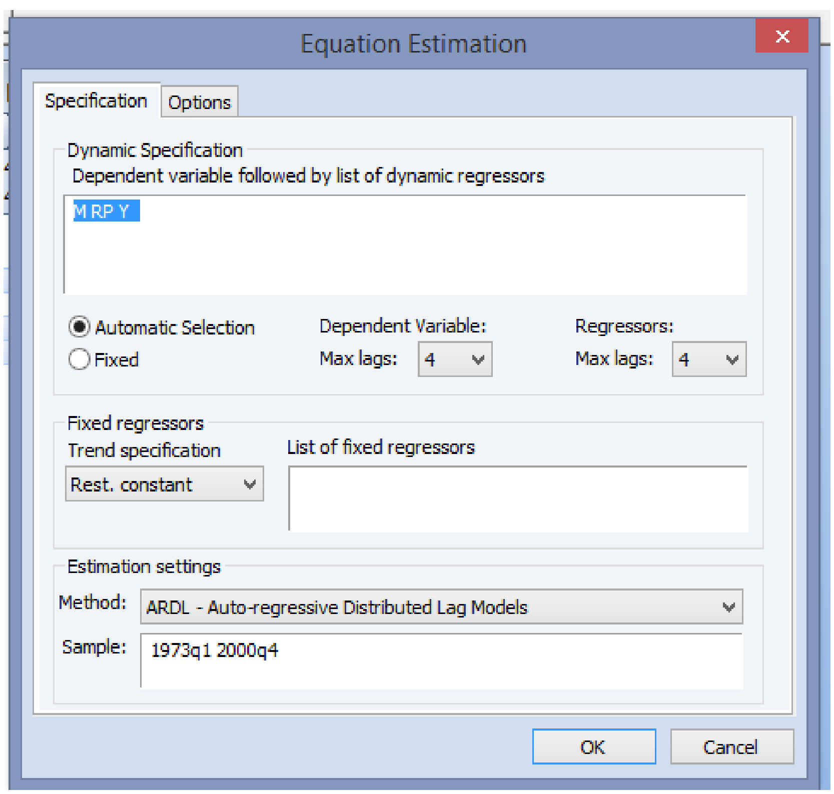
  Computed F-statistic is 2.638 for ARDL(8), and 1.935 for ARDL(12). Both F-statistics are below the lower bound, 3.182 (10%), there for no cointegration among *m*, *y* and *rp*.

EViews 9 by default

Step 1:- Select the variables – the first selected is dependent variable. **M RP Y**
Go to <Equation Estimation>
Select <ARDL…> from [Method:]



Determine the MAXIMUM lag length under <Specification>
Go to <Options> *if necessary*.



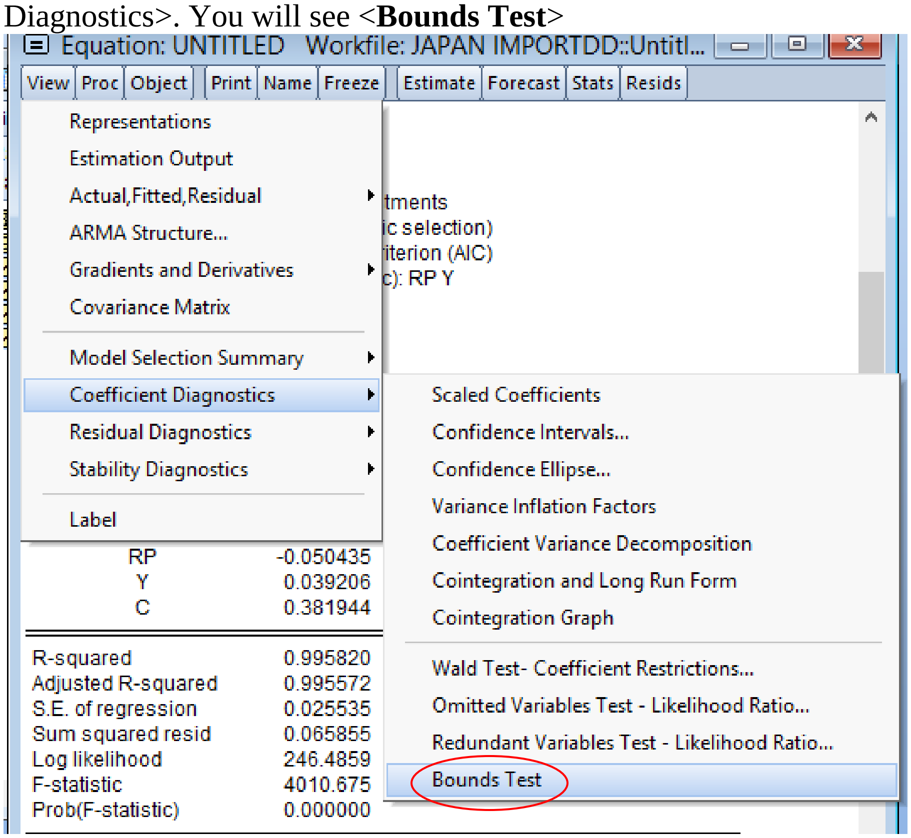
Dependent Variable: M
Method: ARDL
Date: 07/29/16 Time: 15:44
Sample (adjusted): 1974Q1 2000Q4
Included observations: 108 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): RP Y
Fixed regressors: C
Number of models evalulated: 100
Selected Model: ARDL(4, 0, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
M(-1)	0.950801	0.097042	9.797858	0.0000
M(-2)	0.242482	0.135066	1.795285	0.0756
M(-3)	-0.110503	0.134640	-0.820731	0.4137
M(-4)	-0.151911	0.089425	-1.698759	0.0924
RP	-0.050435	0.013659	-3.692407	0.0004
Y	0.039206	0.031296	1.252748	0.2132
C	0.381944	0.155318	2.459107	0.0156

R-squared	0.995820	Mean dependent var	4.167874
Adjusted R-squared	0.995572	S.D. dependent var	0.383739
...	...	...	...

*Note: p-values and any subsequent tests do not account for model selection.

Step 2:- To run Bounds testing for cointegration, go to <View>, and select <Coefficient Diagnostics>. You will see <**Bounds Test**>



ARDL Bounds Test
Date: 07/29/16 Time: 15:43
Sample: 1974Q1 2000Q4
Included observations: 108
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	**6.316940**	2

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.63	3.35
5%	3.1	3.87
2.5%	3.55	4.38
1%	4.13	5

Test Equation:
Dependent Variable: D(M)
Method: Least Squares
Date: 07/29/16 Time: 15:43
Sample: 1974Q1 2000Q4
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(M(-1))	0.003489	0.094826	0.036790	0.9707
D(M(-2))	0.243894	0.088512	2.755481	0.0070
D(M(-3))	0.123059	0.089545	1.374261	0.1724
C	0.396489	0.156537	2.532875	0.0129
RP(-1)	-0.053611	0.014430	-3.715152	0.0003
Y(-1)	0.048222	0.030651	1.573269	0.1188
M(-1)	-0.077844	0.020651	-3.769503	0.0003

R-squared	0.316190	Mean dependent var	0.010029
Adjusted R-squared	0.275568	S.D. dependent var	0.030068
S.E. of regression	0.025592	Akaike info criterion	-4.430467
Sum squared resid	0.066149	Schwarz criterion	-4.256625
Log likelihood	246.2452	Hannan-Quinn criter.	-4.359981
F-statistic	7.783656	Durbin-Watson stat	1.874358
Prob(F-statistic)	0.000001		

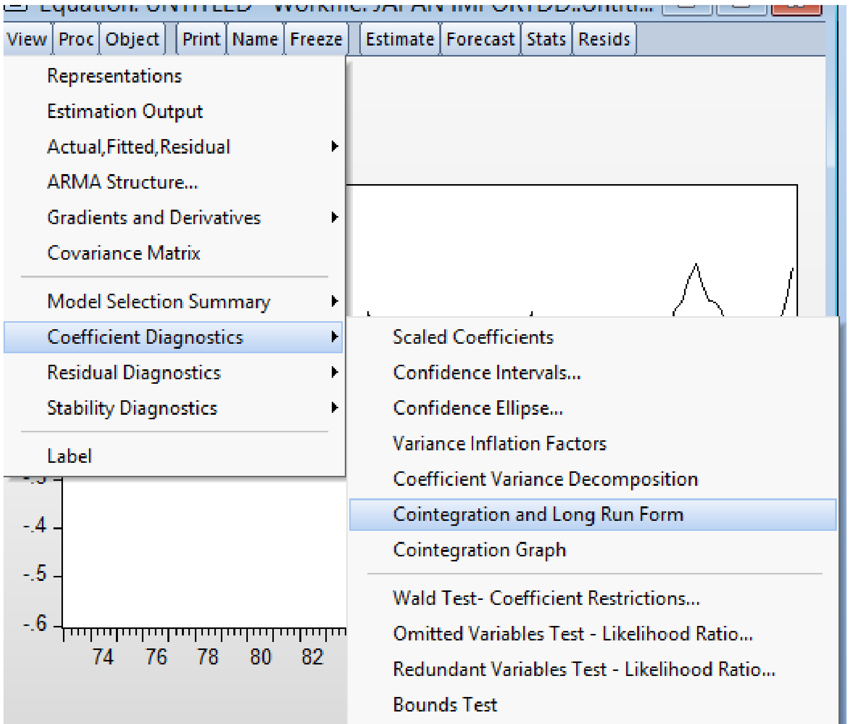
Unrestricted **Error-Correction Model -** ARDL(4, 0, 0) for (**M RP Y**), see Equation (1).

<= short-run (first differenced)

<= *unrestricted* error-correction term (level in one year lag).

It is only to generate the bounds test statistic.

Step 3:- Long-run and short run estimates:- Click <Coefficient diagnostics> then go to <Cointegration and Long Run Form>



ARDL Cointegrating And Long Run Form
Original dep. variable: M
Selected Model: ARDL(4, 0, 0)
Date: 07/29/16 Time: 15:48
Sample: 1973Q1 2000Q4
Included observations: 108

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(M(-1))	0.002750	0.093419	0.029442	0.9766
D(M(-2))	0.221061	0.091712	2.410379	0.0177
D(M(-3))	0.130210	0.089324	1.457733	0.1480
D(RP)	-0.017241	0.042689	-0.403883	0.6872
D(Y)	0.276810	0.233709	1.184422	0.2390
CointEq(-1)	**-0.071805**	**0.015878**	**-4.522193**	**0.0000**

Cointeq = M - (-0.7295*RP + 0.5671*Y **+ 5.5248**)

Error-Correction Model, ECM

<= short-run (first differenced)

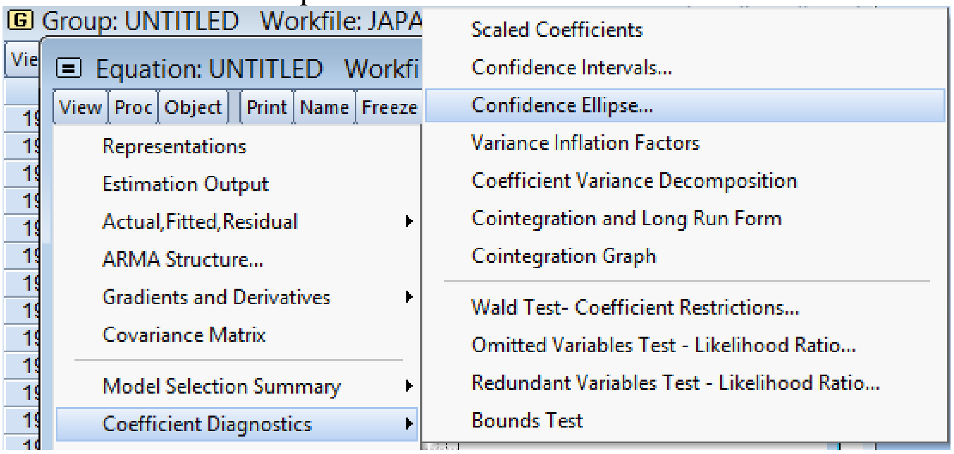
<= Error-correction term i.e. lagged one period residuals, actual M minus estimated M.

Long Run Coefficients

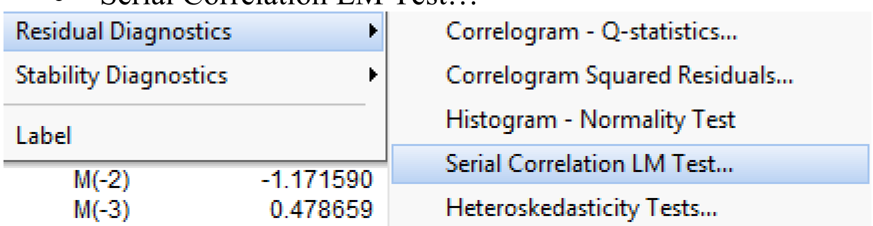
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RP	-0.729544	0.252453	-2.889823	0.0047
Y	0.567117	0.350318	1.618863	0.1086
C	**5.524797**	**2.776588**	**1.989779**	**0.0493**

Diagnostics Check

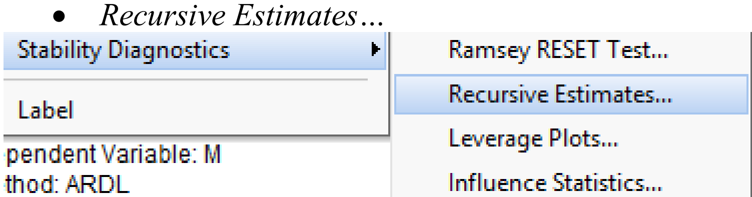
- Confidence Ellipse…

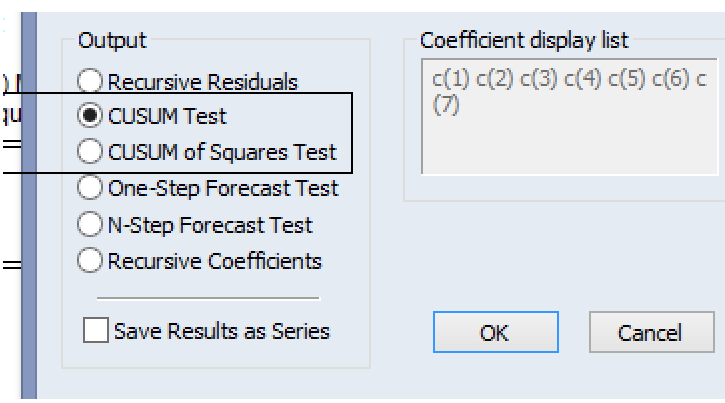


- Serial Correlation LM Test…



- *Recursive Estimates…*





Selected Readings

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APPENDIX –CASE FOR APPLICATION

Aggregate Import Demand Function for Japan

The existing literature has empirically approached standard formulation of import demand equation that relating the quantity of import demanded to domestic real income and relative price of imports. This specification of imports demand corresponds to that of the imperfect substitute model, which implies the existence of imports and domestic production as well as intra-industry trade. By assuming zero degree homogeneity, and of the supply elasticity is infinite or at least large, single equation of imports demand (equation 1) can be consistently estimated.

$$M_t = f\,(Y_t, RP_t)$$

where M is the desired quantity of imports demanded at period t, Y is the real income (domestic real activity). RP is the relative price of imports that is the ratio of import price to domestic price level. And the double-log linear form of data-driven import demand regression is given in equation below .

$$Ln M_t = a_1 + a_1 Ln Y_t + a_2 Ln RP_t + e_t$$

Data

The data for the candidate variables are from OECD Main Economic Indicators. The quarterly data covers the sample period 1973:1 - 2000:4 (in indexes and in 1995 prices). All variables are in natural logarithm form.

m = log of aggregated imports demand (in 1995 prices, index)
y = log of real Gross Domestic Product, GDP (in 1995 prices, index)
rp = log of ratio of import price to domestic price level (proxied by GDP deflator) (in 1995 prices, index)

EViews work file – **japan importdd.wf1**